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Joint Service Aircrew Mask (JSAM) – Rotary Wing (RW): MPU-5 Noise Attenuation Performance

Billy Swayne
Ball Aerospace and Technologies Corp.
Dayton, OH

Hilary Gallagher
Warfighter Interface Division
Battlespace Acoustics Branch
Wright-Patterson AFB, OH

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711 HUMAN PERFORMANCE WING,
AIRMAN SYSTEMS DIRECTORATE,
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433
AIR FORCE MATERIEL COMMAND
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//signed//
HILARY GALLAGHER
Work Unit Manager
Battlespace Acoustics Branch

//signed//
JOHN S. FRAZEY, LTCOL
Chief, Battlespace Acoustics Branch
Warfighter Interface Division

//signed//
WILLIAM E. RUSSELL
Chief, Warfighter Interface Division
Airman Systems Directorate
711 Human Performance Wing

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Billy Swayne *
Hilary Gallagher

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711 HPW/RHCB
2610 Seventh Street
Wright-Patterson AFB, OH 45433

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Air Force Materiel Command
Air Force Research Laboratory
711 Human Performance Wing
Airman Systems Directorate
Warfighter Interface Division
Battlespace Acoustics Branch
Wright-Patterson AFB OH 45433

*Ball Aerospace and Tech Corp.
2875 Presidential Drive
Fairborn OH 45324

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14. ABSTRACT
Noise attenuation measurements were conducted in accordance with American National Standards Institute (ANSI) S12.6-1997 Methods for Measuring the Real-Ear Attenuation of Hearing Protectors on the Joint Service Aircrew Mask (JSAM) – Rotary Wing (RW) MPU-5 with the HGU-56/P with Communications Ear Plugs (CEP) and the HGU-84/P with CEP. Baseline measurements were also conducted with the HGU-56/P and HGU-84/P flight helmets alone. Additional non-ANSI standard attenuation measurements were conducted on the MPU-5 with the Optimized Top Owl (OTO) with CEP and OTO flight helmet alone. The objective of these measurements was to determine if the JSAM-RW performance specification requirements were being met. When worn in combination with the HGU-56/P, HGU-84/P and OTO flight helmets, the MPU-5 with CEP configuration increased noise attenuation across all frequencies, ranging from 125 Hz to 8000Hz, when compared to the helmet only configurations.

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EXECUTIVE SUMMARY

The noise environment on or around a rotary wing aircraft can be hazardous to hearing and degrade speech communication performance. Flight helmets have been required to protect the pilot from potentially hazardous noise exposure and provide effective speech communication capabilities. Chemical/biological (CB) protective equipment has also been required to protect aircrew in an actual or perceived CB warfare environment. Wearing CB protective equipment under a flight helmet could potentially degrade the noise attenuation performance of the helmet and earcups. Noise attenuation measurements were collected in accordance with the American National Standards Institute (ANSI) S12.6-1997 Methods for Measuring the Real-Ear Attenuation of Hearing Protectors[1] on the HGU-56/P and HGU-84/P flight helmets with and without the Joint Service Aircrew Mask (JSAM)-Rotary Wing (RW) MPU-5 and Communications Ear Plugs (CEP). Additional non-ANSI attenuation measurements were conducted on the MPU-5 with the Optimized Top Owl (OTO) with CEP and OTO flight helmet alone. Measurements were conducted at the Air Force Research Laboratory (AFRL) bioacoustics facilities at Wright-Patterson Air Force Base (WPAFB) in May 2016. The results were compared to the JSAM-RW performance specification requirements for ground and in-flight operations. When the MPU-5 was worn in combination with CEP and the flight helmets measured in this study, the MPU-5 met JSAM-RW performance specifications and exceeded the attenuation performance of the helmets alone.

1.0 INTRODUCTION

The noise environment in the cockpit of military aircraft can be hazardous to hearing and degrade speech communication performance. Flight helmets have been required to reduce the risk of hearing loss and hearing related disabilities and provide effective speech communication capabilities. Chemical/biological (CB) protective equipment has also been required to protect aircrew in an actual or perceived CB warfare environment. Wearing CB protective equipment under a flight helmet could potentially degrade the noise attenuation performance of the helmet and earcups and consequently may degrade speech intelligibility performance.

The HGU-56/P, HGU-84/P and Optimized Top Owl (OTO) flight helmets (Figure 1) have been donned by military helicopter pilots to combat noise in the cockpit and to provide satisfactory voice communications. The HGU-56/P and HGU-84/P were rotary wing aircrew helmet systems manufactured by Gentex Corporation. The OTO was a helmet subsystem developed for rotary wing aircrew and manufactured by Thales.

The HGU-56/P (left panel in Figure 1) shell was a hybrid composite made from SPECTRA® and graphite embedded in an epoxy matrix. This design allowed the HGU-56/P shell to flex during an impact as a means of dissipating energy. The energy absorbing liner was made from expanded bead polystyrene that was thicker and had a lower density than liners used in most other flight helmets. The fitting liner was an Oregon Aero Zeta II liner. The chin strap was a "British Buckle" that featured D-ring and snap fasteners for rapid removal in the event of an emergency. The

earcups attached to the retention with Velcro for adjustability ease. The dual visor module assembly included outer dark and inner clear impact-resistant, ultraviolet-absorbing lenses.

The HGU-84/P (center panel in Figure 1) was composed of a rigid Graphlon® composite shell that was pressure-molded laminate graphite and ballistic nylon. The HGU-84/P frontal opening was cut back for maximum peripheral vision. The helmet was lightweight and equipped with tapered earcups, cushioned earseals, and spacer pads. A half-inch thick Styrofoam™ energy-absorbing liner provided impact protection and an Oregon Aero Zetaliner was installed for a comfortable and stable fit. Its unique one-piece integrated chin-and-nape strap was threaded through the helmet and adjusted to provide a stable fit.

The OTO subsystem (right panel in Figure 1) was a modular combination of avionics displays and a protective flying helmet. The system was capable of presenting symbology to the pilot, day or night, wherever the pilot's head was positioned. The modular headgear consisted of the custom-fit basic helmet and the attached Dual Visor Module (DVM), and alternatively a Day Display Module (DDM) or a Night Display Module (NDM). Pilot customization of the OTO helmet used a laser scan of the pilot's head to mill out a personalized Energy Absorbing (EA) liner to exactly match the contours of the pilot's head. This ensured the best fit and alignment of the optical display from the display unit.

Figure 1. Flight helmets (left to right): HGU-56/P, HGU-84/P, and OTO.

The JSAM-RW MPU-5 was designed specifically for all rotary wing aircraft for all military services, excluding the AH-64 Apache helicopter, and has provided CB protection during ground escape and evasion. The MPU-5 system was integrated with all applicable aircraft and aircrew systems, including seating, restraint systems, night-vision goggles, vision correction, laser eye protection, and communication systems. The MPU-5 enabled the aviator to have sufficient mobility and field of regard to access critical aircraft controls and displays, was body-mounted to enable MPU-5 integration without aircraft modification, and was compatible with all Aircrew Flight Equipment and Individual Protection Equipment.

The MPU-5 was issued in multiple sizes to accommodate various face/head size combinations. Each MPU-5 consisted of three major subassemblies; (1) hood/hoodring subassembly, (2) face plate subassembly and (3) supply subassembly. The hood assembly and face plate assembly are shown in Figure 2. Due to the nature of sound attenuation measurements, the supply subassembly was not attached to the MPU-5 during the measurements. The flight helmets, in combination with the MPU-5, are shown in Figure 3.

Figure 2. MPU-5

Figure 3. Flight helmets with MPU-5 (left to right): HGU-56/P, HGU-84/P, and OTO.

Communications Ear Plugs (CEP) were included in the helmet/hood configuration in order to improve the noise attenuation and speech intelligibility performance of the system. CEP were passive hearing protection devices composed of cabling designed to deliver a mono audio signal to the user via non-custom foam ear tips (Figure 4). The CEP cabling (CEP515-C21) was non-vented and suitable for use in rotary aircraft and ground support

operations. The foam ear tips were Comply™ Canal Tips, available in four sizes: slim, short, standard, and large.

Figure 4. CEP (foam ear tips with communication cabling)

The objective of this study was to measure the noise attenuation performance of the HGU-56/P, HGU-84/P, and OTO flight helmets with the MPU-5 and CEP to determine if JSAM-RW specification requirements were met. Measurements with the helmets alone were also conducted to provide the baseline for comparison. The performance specification requirement threshold (T) and objective (O) are shown below.

> [*58]* *The JSAM RW when integrated with helmets in Appendix D shall result in no more than a 3 dB degradation of the measured one-third octave band hearing attenuation compared to the original (non-JSAM) configuration (T). The JSAM RW when integrated with helmets in Appendix D shall result in no more than a 3 dB degradation of the measured one-third octave band hearing attenuation compared to the original (non-JSAM) configuration without the use of ancillary noise protection devices such as communication earplugs (CEP), ACCES, or PACS devices (O).*

2.0 METHODS

2.1 Subjects

Twenty paid volunteer subjects (10 male, 10 female) participated in the continuous noise attenuation performance measurements for the helmet/MPU-5/CEP configurations. Ten of those subjects (5 male, 5 female) participated in the continuous attenuation performance measurements for the helmet only configurations. The subjects ranged in age from 18 to 34. All subjects were required to have a technician administered screening audiogram via the Hughson-Westlake method, with hearing thresholds inside the normal hearing range, 25 dB hearing level (HL) or better from 125 Hz to 8000 Hz. Sizing and all helmet and hood fittings were conducted by a JSAM-RW subject matter expert. Ear tip size was selected and verified by the Test Administrator. Helmet, hood, and ear tip sizes were recorded and are listed in Table 1. Items marked with an "*" indicate that additional padding was required for the helmet alone configuration to achieve proper fit. The additional padding was removed for the helmet with MPU-5 configuration. Items marked with a "**" indicate that the helmet employed in the MPU-5 configuration was one size larger than the helmet used for the helmet alone configuration.

Table 1. Subject sizing matrix

Subject ID	HGU-56/P	HGU-84/P	MPU-5	Comply Canal Tip
1382	XXS	Medium	Small	Standard
1487	XXS	Medium	Medium	Slim
1534	Large	X-Large	X-Large	Large
1584	Medium	Large	X-Large	Standard
1599	Medium	Medium	Large	Large
1601	Large	X-Large	X-Large	Large
1602	XXS +1.5 pads*	Medium	Large	Large
1622	Small	Large	Small	Standard
1625	Small +1 pad*	Medium	Large	Standard
1628	Medium	Large	X-Large	Standard
1629	Medium	Large/ X-Large**	X-Large	Large
1630	XXS +.5 pad*	Medium	Large	Slim
1631	Large	X-Large	X-Large	Standard
1633	Medium +1 pad*	Large	X-Large	Standard
1638	XXS	Medium	Large	Slim
1641	Small	Large	Large	Slim
1651	Small	Large	Medium	Standard
1671	Small	Large	Medium	Standard
1673	XXS	Medium	Small	Slim
1674	Medium	Large	Large	Large

Two additional subjects (1 male, 1 female) participated in the continuous noise attenuation performance measurements for the OTO helmet. The number of subjects for this portion of the study was limited due to the fact that the helmets were custom fit to individual aircrew members. These subjects received the same screening audiogram and facility training session as the other subjects. Both subjects were AH-1Z and UH-1Y pilots who traveled from the Naval Air Station Patuxent River, Maryland to the lab at WPAFB. The male pilot was sized with an x-large MPU-5 and standard size Comply Canal Tips. The female pilot was sized with a large MPU-5 and slim Comply Canal Tips. The OTO helmets were previously custom fit to each pilot.

2.2 Continuous Noise Attenuation

The AFRL facility used for this study was specifically built for the measurement of the sound attenuation properties of passive hearing protection devices. The chamber (Figure 5), its instrumentation, and measurement procedures were in accordance with ANSI S12.6-1997[1]. The subjects were seated in the center of the room and tasked to respond to a series of tones using a hand-held response wand (Figure 6). ANSI S12.6 required measuring the occluded (with hearing protector in place) and unoccluded hearing threshold of human subjects using a von Békésy tracking procedure. The thresholds were measured two times for the unoccluded ear condition and two times for the occluded ear condition. The real-ear attenuation at threshold for each subject was computed at each octave band frequency, 125 to 8000 Hz, by averaging the two trials (the difference between unoccluded and occluded ear hearing thresholds). Due to the ambient noise requirement of ANSI S12.6-1997, the subassembly and blower were not attached to the MPU-5 for these attenuation measurements.

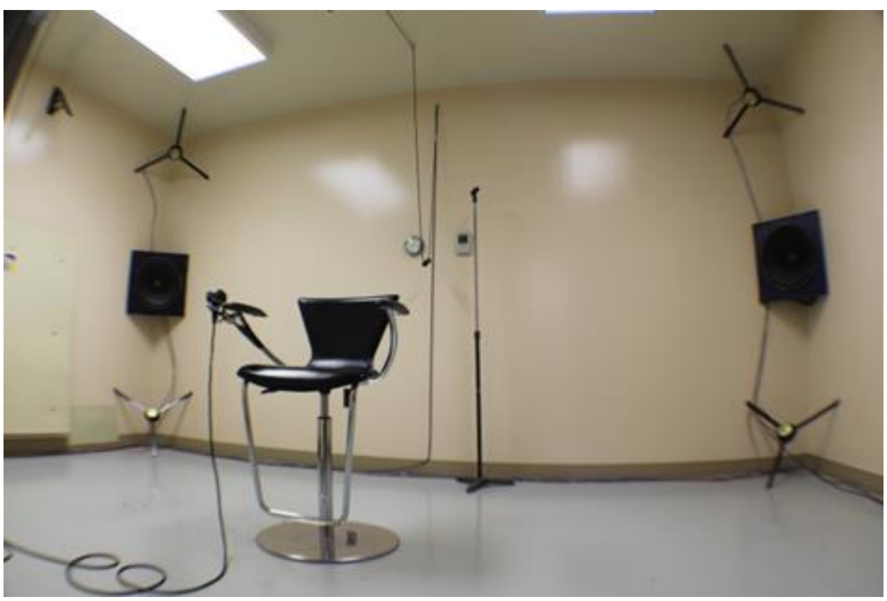

Figure 5. Facility used for measurement of passive continuous noise attenuation

Figure 6. Subject completing the threshold measurement with the MPU-5 and HGU-56/P with CEP

3.0 RESULTS

ANSI S12.6 measurements of the HGU-56/P and HGU-84/P flight helmets were collected with and without the MPU-5 and CEP. Additionally, attenuation measurements of the OTO flight helmet were collected with and without the MPU-5 and CEP. The OTO attenuation measurements were conducted according to ANSI S12.6 with the exception of the number of subjects. The cost and availability of the OTO, in addition to the time and resources required to customize the helmet, limited the sample size to two. The results were analyzed to compare the noise attenuation performance of the helmets alone with the helmet/MPU-5/CEP configuration in order to understand the effect the MPU-5 hood has on the noise attenuation performance of each helmet. The requirement stated that the addition of the MPU-5 shall not degrade the noise attenuation of the helmet by more than 3dB.

3.1 Continuous Noise Attenuation Results

Passive noise attenuation data were analyzed using the methods described in ANSI S12.68-2007 Methods of Estimating Effective A-Weighted Sound Pressure Levels When Hearing Protectors are Worn[2]. This ANSI standard detailed the methods for estimating the effective A-weighted Sound Pressure Level (SPL) when hearing protectors are worn. The octave band method was the "gold standard" method for estimating a users' noise exposure. This method required both the noise spectra per octave band and the attenuation data per octave band. Mean and standard deviation (SD) noise attenuation data were calculated across subjects at each octave band frequency. The helmet attenuation per octave band was

subtracted from the helmet/MPU-5/CEP configuration attenuation per octave band to determine if there was a reduction in attenuation (Table 2 and Figure 7). A single Noise Reduction Rating (NRR) was also calculated for mean minus 1 and mean minus 2 SD. Figures 8-10 display a graphical representation of the mean minus 2 SD attenuation results at each measured frequency for each helmet with and without the MPU-5 and CEP. When worn in combination with the flight helmets, the MPU-5 with CEP increased noise attenuation performance across all frequencies, ranging from 125 Hz to 8000Hz, when compared to the flight helmets alone. Mean minus 2 SD noise attenuation performance increased by a range of 18-44 dB for the HGU-56/P, 17-40 dB for the HGU-84/P, and 6-37 dB for the OTO.

Table 2. Passive mean and standard deviation noise attenuation data as well as NRR for flight helmets with and without MPU-5 and CEP

Helmet / Combination		Frequency (Hz) 125	250	500	1000	2000	4000	8000	NRR Mean-1SD	NRR Mean-2SD
HGU-56/P	Mean	2	1	8	20	27	29	31	7	3
	SD	4	5	3	4	4	5	8		
HGU-56/P with MPU-5 & CEP	Mean	25	25	34	40	45	62	69	29	22
	SD	6	7	6	4	4	4	5		
Difference in Mean (dB)		**23**	**24**	**26**	**20**	**18**	**33**	**38**		
HGU-84/P	Mean	5	7	12	21	26	36	41	11	5
	SD	8	6	4	3	6	7	9		
HGU-84/P with MPU-5 & CEP	Mean	24	29	36	42	47	62	71	31	23
	SD	8	8	7	5	4	3	4		
Difference in Mean (dB)		**19**	**22**	**24**	**21**	**21**	**26**	**30**		
Optimized Top Owl (OTO)	Mean	10	8	17	24	34	48	53	14	10
	SD	6	4	5	5	5	3	4		
OTO with MPU-5 & CEP	Mean	32	33	44	43	44	63	71	36	29
	SD	9	6	0	2	7	7	1		
Difference in Mean (dB)		**22**	**25**	**27**	**19**	**10**	**15**	**18**		

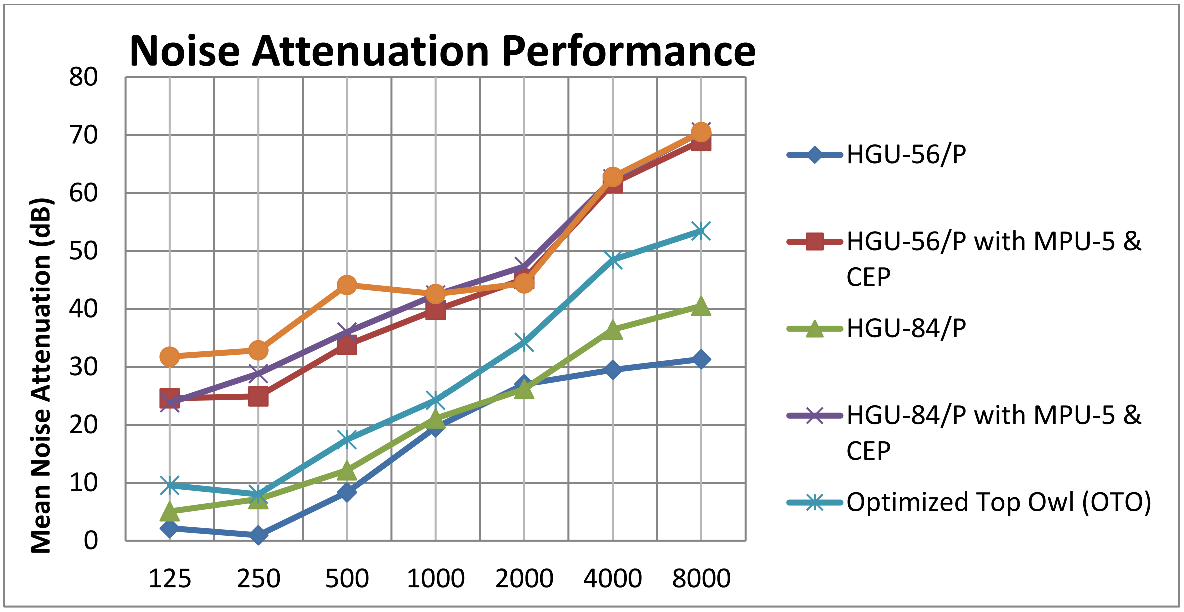

Figure 7. Mean noise attenuation data for flight helmets with and without MPU-5 and CEP

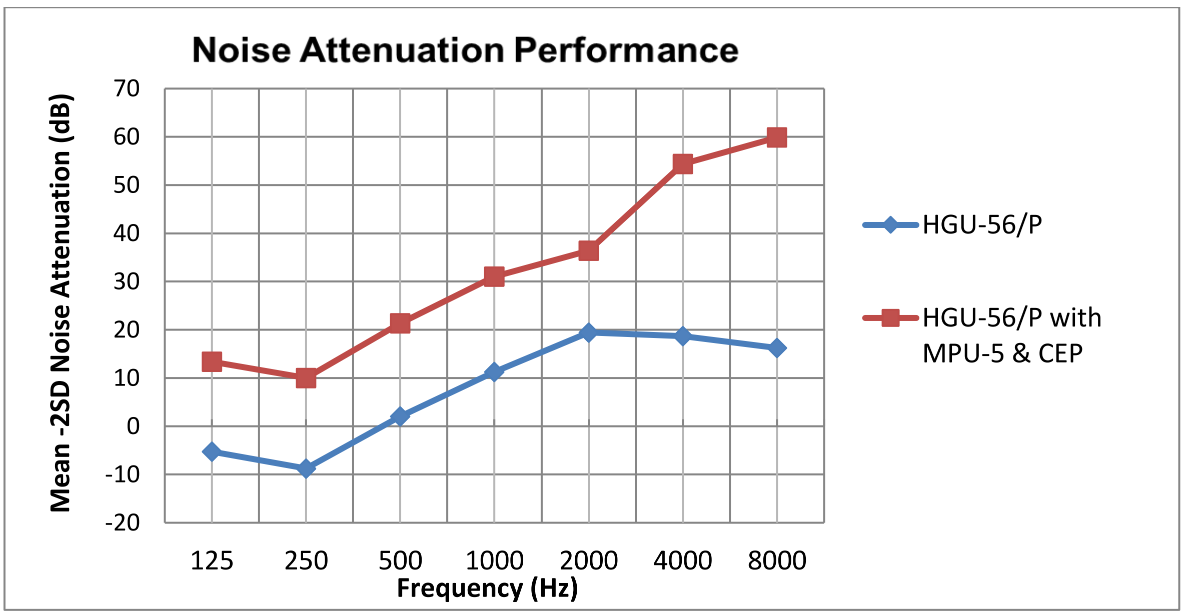

Figure 8. Mean-2SD noise attenuation data for HGU-56/P with and without MPU-5 and CEP

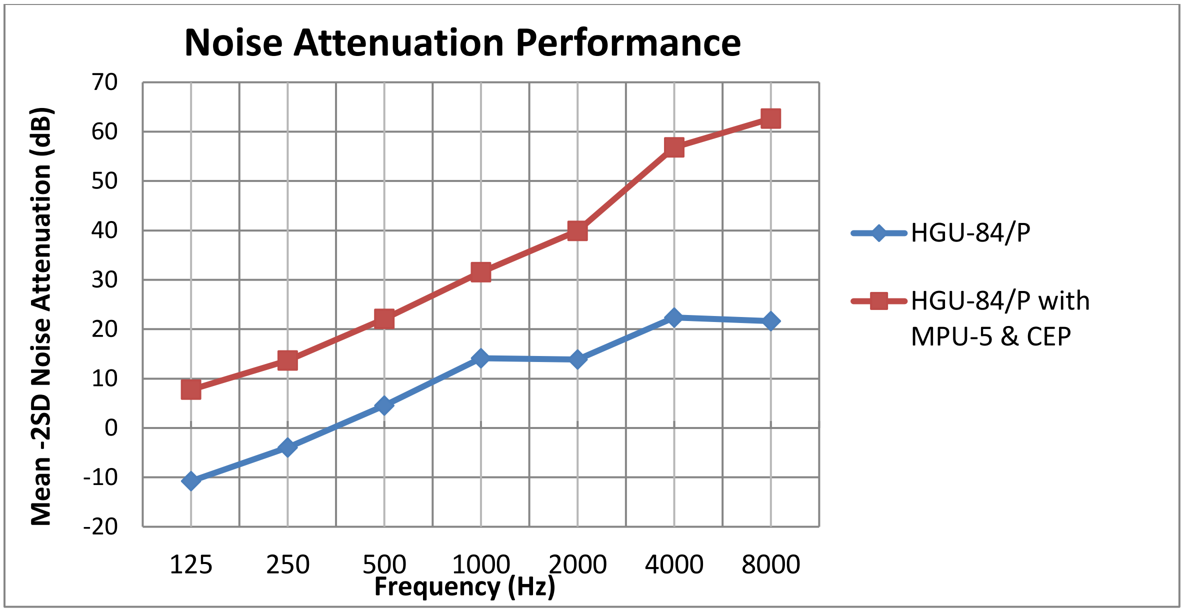

Figure 9. Mean-2SD noise attenuation data for HGU-84/P with and without MPU-5 and CEP

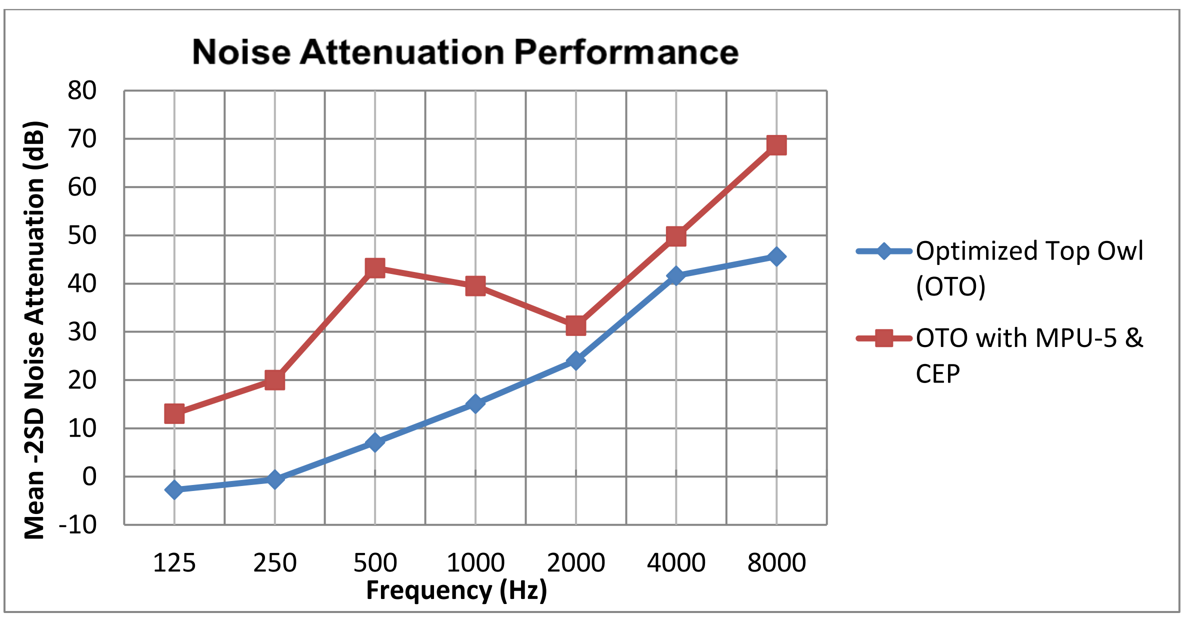

Figure 10. Mean-2SD noise attenuation data for OTO with and without MPU-5 and CEP

4.0 DISCUSSION

Any material or cable that breaks the seal of an earcup in a headset or helmet has the potential to create an acoustic leak. Therefore the JSAM-RW performance specification requirement was developed assuming that some degree of degradation, while unavoidable, would be acceptable. The requirement stated that the MPU-5, worn in combination with a flight helmet, should degrade the noise attenuation performance of the helmet by no more than 3 dB across all frequencies when compared to the attenuation performance of the helmet alone for it to be acceptable.

The solution to ensure the requirement was met was to add a communication earplug, e.g. CEP, to the MPU-5 ensemble. Speech intelligibility measurements should also be conducted to understand the performance capabilities of the helmet/MPU-5/CEP configuration and determine if it provides the necessary communication needs when the MPU-5 would be required.

5.0 CONCLUSIONS

Noise attenuation data were collected on the HGU-56/P, HGU-84/P, and OTO flight headsets with and without the JSAM-RW MPU-5 and CEP. When worn in combination with the HGU-56/P, HGU-84/P, and OTO flight helmets, the MPU-5 with CEP increased noise attenuation performance across all frequencies, ranging from 125 Hz to 8000Hz, when compared to the helmets alone. Therefore the MPU-5, when worn with CEP meets the threshold performance specification requirement.

6.0 REFERENCES

1. ANSI S12.6-1997 Methods for Measuring the Real-Ear Attenuation of Hearing Protectors Systems.
2. ANSI S12.68-2007 Methods of Estimating Effective A-Weighted Sound Pressure Levels When Hearing Protectors are Worn

LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS

AFRL	Air Force Research Laboratory
ANSI	American National Standards Institute
CB	Chemical/Biological
CEP	Communication Earplugs
dB	Decibel
DDM	Day Display Mode
DVM	Dual Visor Mode
EA	Energy Absorbing
HL	Hearing Level
JSAM RW	Joint Service Aircrew Mask- Rotary Wing
NDM	Night Display Mode
NRR	Noise Reduction Rating
OTO	Optimized Top Owl
REAT	Real Ear Attenuation at Threshold
SD	Standard Deviation
SPL	Sound Pressure Level
WPAFB	Wright Patterson Air Force Base